B68 12023

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: Variation in S-IVB Optimal Second MR-Shift Time with Orbital Altitude for AAP - Case 610

DATE: December 5, 1968

FROM: I. Hirsch

ABSTRACT

In order to optimize launch vehicle payload performance over the range of altitudes of interest to AAP viz. 81 to 260 nm, computer simulations were made to determine the variation of the optimal second-mixture-ratio (MR) shift time with altitude. The optimal duration of the second-MR burn is shown to decrease almost linearly from 330 seconds at 81 x 81 nm to 203 seconds for circular orbits of 260 nm.

Simulations in this study also provided data on the payload capability of Vehicle-209 for circular orbits ranging in altitudes from 81 to 260 nm. MSFC's restriction that the second-MR shift occur no later than 280 seconds after S-IVB ignition requires that a non-optimal shift time be used for circular orbits below 148 nm, resulting in a maximum loss of 100 pounds of payload at 81 nm.

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(NASA-CR-100305) VARIATION IN S-4B OPTIMAL SECOND MR-SHIFT TIME WITH ORBITAL ALTITUDE FOR AAP (Bellcomm, Inc.) 8 p

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MEMORANDUM FOR FILE

I. Introduction

The variation of payload inserted into an 81 x 120 nm orbit with respect to the time of second mixture-ratio (MR) shift during the powered flight of the S-IVB stage has been reported in Reference 1. It was shown that the payload has a parabolic dependence on the duration of the second MR burn, T_2, reaching a maximum at some critical value of T_2, say T_2^*. These results have been extended to include the variation of T_2^* with altitude for a range of circular orbits of interest to AAP.

II. Variation of Optimal MR-Shift Time with Orbital Altitude

Since the second MR-shift time during the S-IVB burn is determined by the initial propellant loading, it is desirable in mission analysis to adjust the duration of the second-MR burn so that the payload is maximized with respect to this parameter. Assuming that the LOX tanks are filled to capacity (190,220 pounds of LOX), the various LH_2 loadings were computed to give different MR-shift times (cf. Reference 1).

Using these LH_2 loadings, simulations to determine T_2^* for circular orbits ranging in altitude from 81 to 260 nm were then made with the BCMASP simulator for Saturn IB trajectories (References 2 and 3). The optimal duration of the second-MR burn is seen in Figure 1 to vary almost linearly from 330 seconds for 81 nm circular orbits to 203 seconds for circular orbits of 260 nm. In Reference 1 it was pointed out that the T_2-versus-payload parabola is relatively flat in a neighborhood of $T_2 = T_2^*$. The payload falls off by no more than 10 pounds for T_2 within ± 5 seconds of T_2^*, so that the points along the curve in Figure 1 should not be interpreted as being extremely critical.

MSFC's constraint that the second mixture-ratio shift occur no later than 280 seconds after S-IVB ignition (which includes a first shift in the mixture ratios at 1.3 seconds after S-IVB ignition), requires that a less-than-optimal value of the MR-shift time be used for altitudes below 148 nm as noted by the dotted line in Figure 1.

III. Payload Capability of Vehicle-209 for Circular Orbits

An added bonus of the simulations described in Section II to determine T_2^* is data on the payload capability of Vehicle-209 for circular orbits ranging in altitudes from 81 to 260 nm. Figure 2 gives the variation in payload with altitude for Vehicle-209, where the payload is optimal with respect to the second MR-shift time for a given altitude. The reduction in payload for altitudes below 148 nm due to the 280-second limitation on the MR-shift time is indicated by a dotted line in Figure 3, with a maximum loss of approximately 100 pounds occurring at 81 nm.

Table I provides a weight summary of Vehicle-209 (in a manned configuration) with the propellant loading adjusted for an optimal MR-shift time for insertion into a 200 x 200 nm orbit, followed by engine performance data for Vehicle-209 in Table II.

I. Hirsch

1025-IH-dcs

Attachments

References

1. Hirsch, I., "Dependence of AAP-3 Payload on S-IVB Second Mixture-Ratio Shift Time - Case 610," Bellcomm Memorandum for File, October 30, 1967.

2. Esposito, V. J., "A Computer Program for Simulating Uprated Saturn I Trajectories," Bellcomm Technical Memorandum, TM-67-1021-2, September 29, 1967.

3. Hirsch, I., "Modifications to the BCMASP Simulator for Saturn IB Trajectories - Case 610," Bellcomm Memorandum for File, March 29, 1968.

4. MSFC, "Revised launch vehicle weight data for AAP reference trajectories," Memorandum R-P&VE-VAW-67-116, August 17, 1967.

5. MSFC, "Weight status report for the Saturn IB launch vehicles," Memorandum R-P&VE-VAW-67-142, November 2, 1967.

6. MSFC, "Engine specific impulse and thrust for application to Saturn vehicles," Memorandum R-P&VE-67-401, August 23, 1967 (CONFIDENTIAL).

7. CCSD, "Launch Vehicle Preliminary Reference Trajectory: AAP-2 Mission," TN-AP-67-198, April 14, 1967.

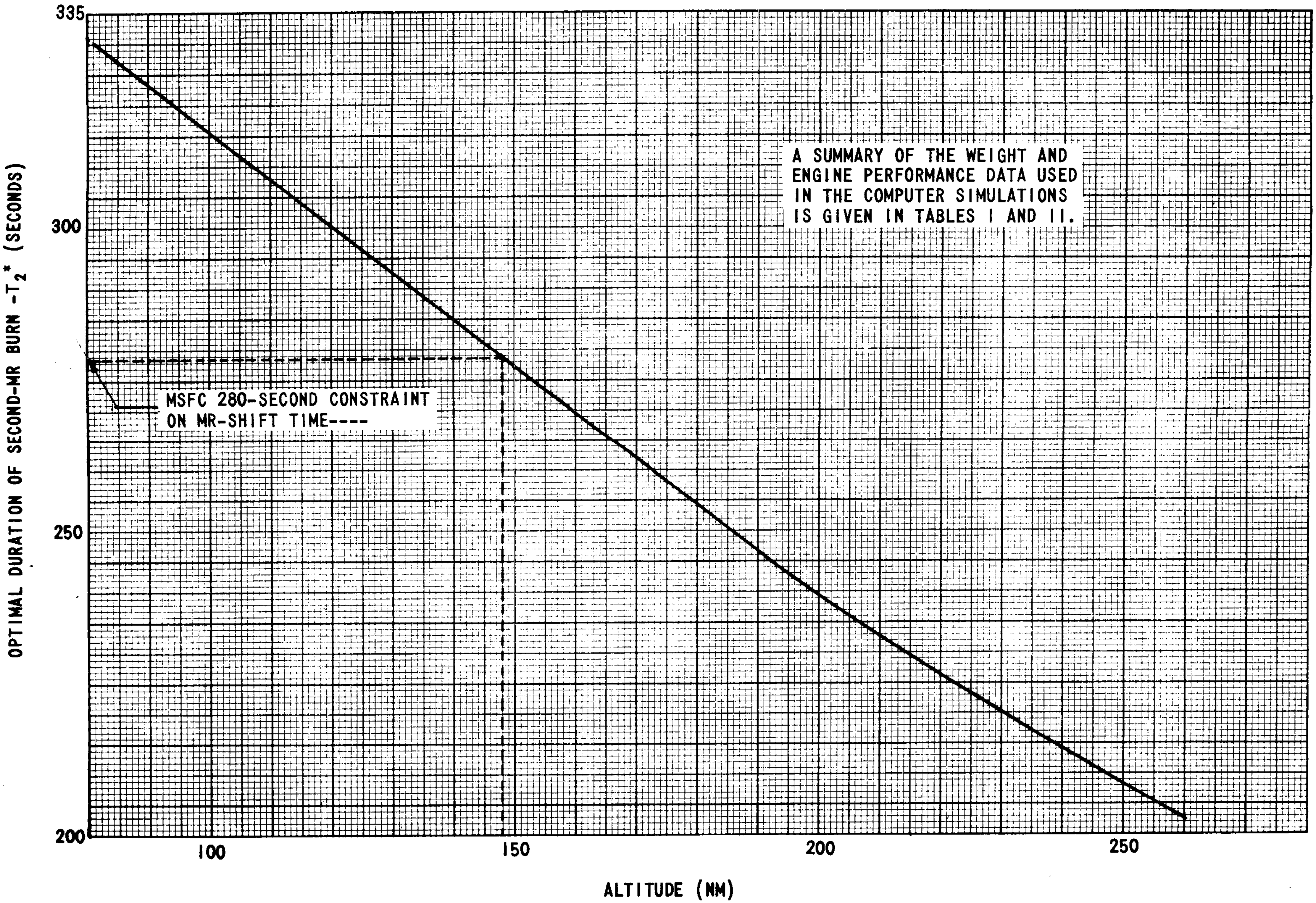

FIGURE I - VARIATION OF OPTIMAL DURATION OF SECOND-MR BURN WITH CIRCULAR ORBITAL ALTITUDE

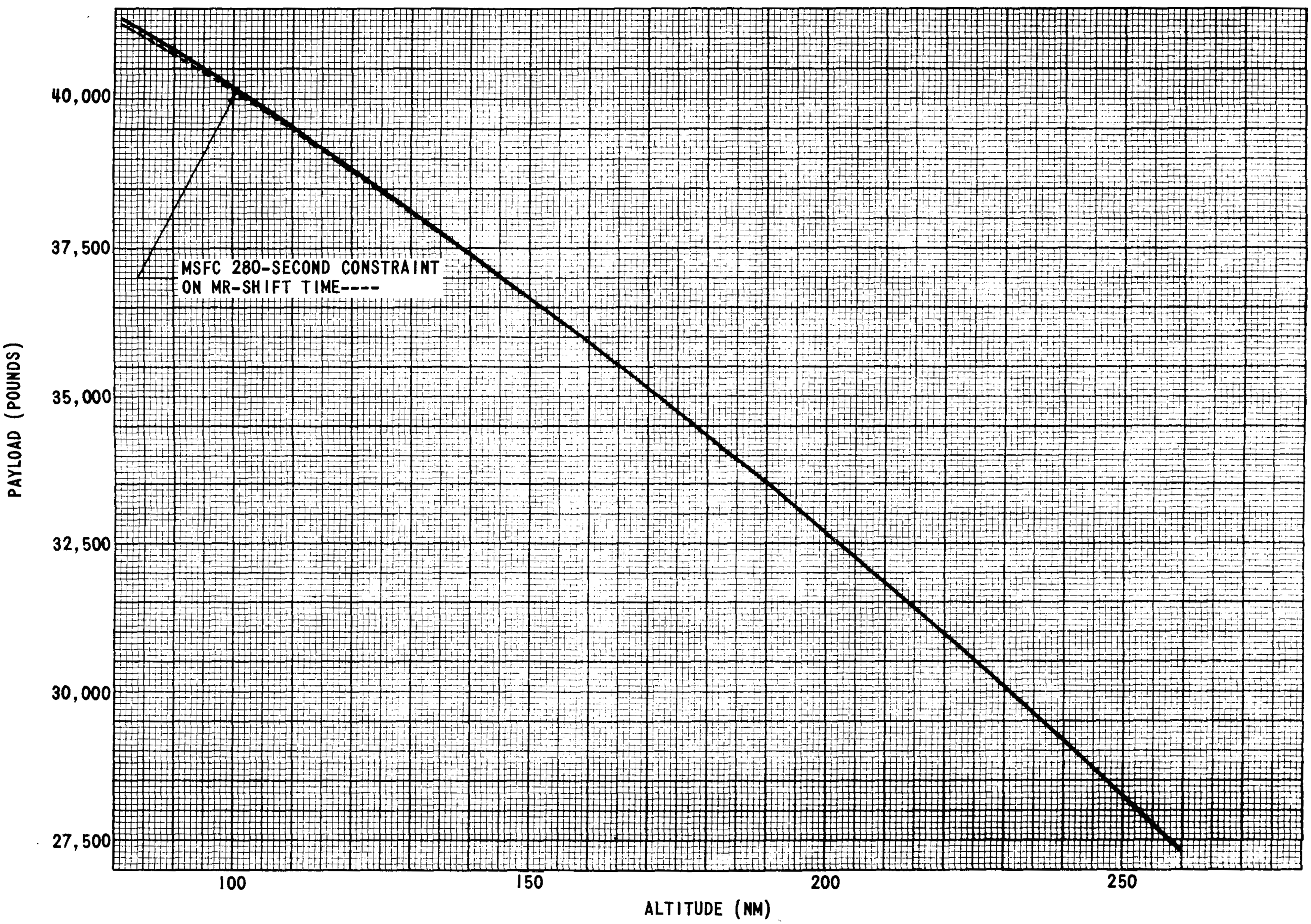

FIGURE 2 - PAYLOAD CAPABILITY OF VEHICLE-209 FOR CIRCULAR ORBITS

TABLE I

Summary of Vehicle-209 Weights (in pounds) for Insertion into a 200 x 200 nm Orbit[1]

62,803	Insertion Weight:
	32,662 - Spacecraft
	4,143 - Instrument Unit
	22,015 - S-IVB Stage, Dry
	1,500 - S-IVB Flight Performance Reserve Propellant (1,250 LOX, 250 LH_2)
	2,483 - S-IVB Residual Propellant
235,797	S-IVB Consumed and Jettisoned Weight:
	190,220 - S-IVB LOX Consumed
	36,912 - S-IVB LH_2 Consumed ($T_2 = T_2^* = 239$ seconds)
	8,450 - Launch Escape System
	215 - S-IVB Ullage Rocket Cases
101,368	S-IB Jettisoned Weight:
	6,514 - S-IVB/S-IB Interstage
	83,761 - S-IB Stage, Dry
	10,492 - S-IB Flight Performance Reserve and Residual Propellant
	601 - Other Items
888,543	S-IB Expended Weight at Separation:
	882,526 - S-IB Propellant Consumed
	4,178 - S-IB Thrust Decay Propellant
	1,000 - S-IB Frost
	839 - Other Items (Includes 100 Pounds S-IVB Frost)
1,288,511	Lift-Off Weight

[1]Based on data in References 4 and 5.

TABLE II

Engine Performance Data for Vehicle-209[2]

S-IB Stage:

Nominal Sea Level Thrust (pounds)	1,679,604.1
Nominal Weight Rate (pounds/second)	6,415.6
Nominal I_{SP} (seconds)	261.8

S-IVB Stage:

Mixture Ratio	5.0	5.542	4.702
Thrust (pounds)	204,519	230,519	189,219
I_{SP} (seconds)	428.3	425.4	429.7
Weight Rate (pounds/second)	477.5	541.9	440.4
Duration of Burn (seconds)	1.3	239.	220.3

[2]Based on data in non-classified section of Reference 6 and Reference 7.

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From: I. Hirsch

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